Evaluating Typhoon Haiyan's Performance and Identifying Storm Surge Prone Areas in Key Locations Across the Philippines using Advanced Circulation (ADCIRC)

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EF Site: DesignSafe – University of Texas At Austin

UNIVERSITY OF GUAM UNIBETSEDÅT GUAHAN

TEXAS The University of Texas at Austin

DESIGNSAFE-CI A NATURAL HAZARDS ENGINEERING COMMUNITY

Natural Hazards Research Engineering Infrastructure (NHERI)

- The Wall of Wind at Florida International University
- The Advanced Technology for Large Structural Systems (ATLSS) Engineering Research Center at Lehigh University
- The O.H. Hinsdale Wave Research Laboratory at Oregon State University
- The NHERI SimCenter at University of California, Berkeley
- The Center for Geotechnical Modeling (CGM) at University of Calfornia, Davis
- The Large High Performance Outdoor Shake Table (LHPOST) at Unversity of California, San Diego
- The Powell Family Structures and Materials Laboratory at University of Florida
- The Large-Scale Mobile Shakers at University of Texas at Austin
- The NHERI Cyberinfrastructure and Data Management team at University of Texas at Austin
- The Rapid Response Research Facility (RAPID) at Unversity of Washington

The O.H. Hinsdale Wave Research Laboratory at Oregon State University

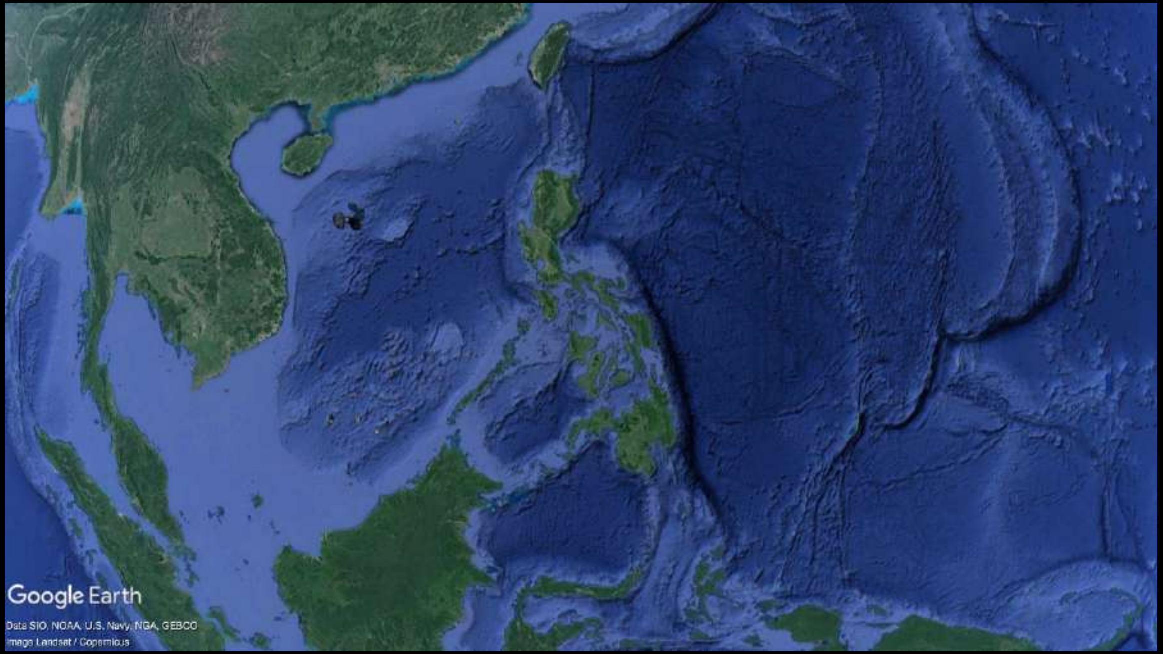
The University of Texas - Austin

Large-Scale Mobile Shakers

Cyberinfrastructure & Data Management

Agenda:

- Introduction/Background
- Methodology
- Results
- Discussion
- Reflection
- Acknowledgment & References



The Philippines

Northwest Pacific Basin – 26 typhoons a year
Philippines Area of Responsibility (PAR) – 20 typhoons a year. Nine make landfall.

Typhoon Haiyan (2013)

Central Pressure: 895 hPa
Wind Speed: 315 kph
Wind Gusts: 379 kph
”Super Typhoon” category or Category 5 in the Saffir-Simpson Scale

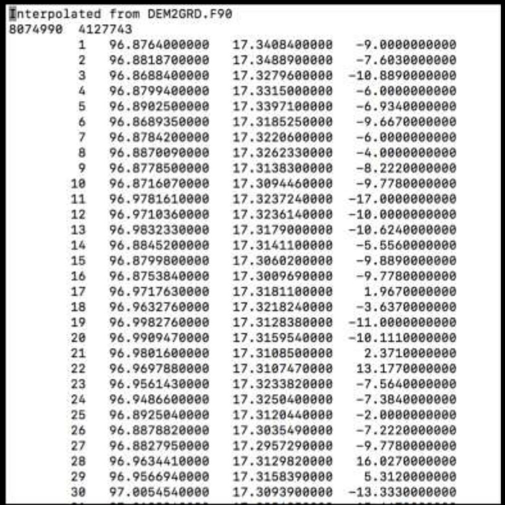
https://upload.wikimedia.org/wikipedia/commons/5/5b/Haiyan_2013-11-07_0630Z.png

- **6,000** fatalities
- **28,000** injuries
- **$800 million** in infrastructure and agricultural damage

https://www.ibtimes.co.uk/typhoon-haiyan-anniversary-40-powerful-photos-storm-that-devastated-philippines-1473294

SMS & ADCIRC

- Surface-water Modelling System (SMS) – creating and simulating surface water models
- Original grid file: 9,598,293 nodes
- Modified grid file: 4,127,743 nodes



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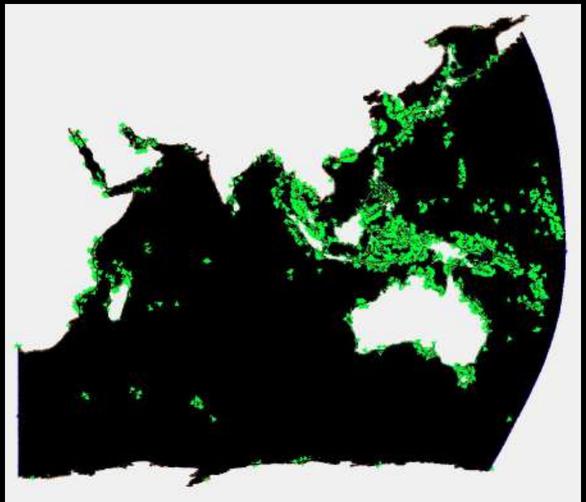
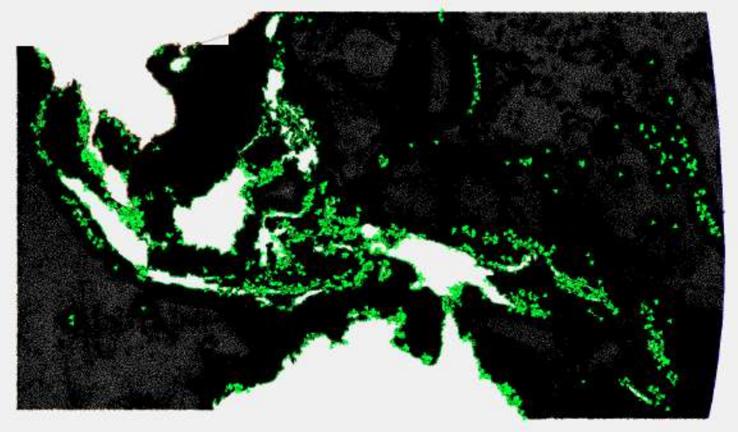
Interpolated from DEM2GRD.F90
8074990  4127743
         1   96.8764000000   17.3408400000   -9.0000000000
         2   96.8818700000   17.3488900000   -7.6030000000
         3   96.8688400000   17.3279600000  -10.8890000000
         4   96.8799400000   17.3315000000   -6.0000000000
         5   96.8902500000   17.3397100000   -6.9340000000
         6   96.8689350000   17.3185250000   -9.6670000000
         7   96.8784200000   17.3220600000   -6.0000000000
         8   96.8870090000   17.3262330000   -4.0000000000
         9   96.8778500000   17.3138300000   -8.2220000000
        10   96.8716070000   17.3094460000   -9.7780000000
        11   96.9781610000   17.3237240000  -17.0000000000
        12   96.9710360000   17.3236140000  -10.0000000000
        13   96.9832330000   17.3179000000  -10.6240000000
        14   96.8845200000   17.3141100000   -5.5560000000
        15   96.8799800000   17.3060200000   -9.8890000000
        16   96.8753840000   17.3009690000   -9.7780000000
        17   96.9717630000   17.3181100000    1.9670000000
        18   96.9632760000   17.3218240000   -3.6370000000
        19   96.9982760000   17.3128380000  -11.0000000000
        20   96.9909470000   17.3159540000  -10.1110000000
        21   96.9801600000   17.3108500000    2.3710000000
        22   96.9697880000   17.3107470000   13.1770000000
        23   96.9561430000   17.3233820000   -7.5640000000
        24   96.9486600000   17.3250400000   -7.3840000000
        25   96.8925040000   17.3120440000   -2.0000000000
        26   96.8878820000   17.3035490000   -7.2220000000
        27   96.8827950000   17.2957290000   -9.7780000000
        28   96.9634410000   17.3129820000   16.0270000000
        29   96.9566940000   17.3158390000    5.3120000000
        30   97.0054540000   17.3093900000  -13.3330000000
```

SMS grid (.grd) file

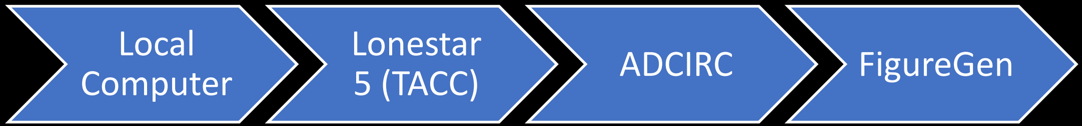
Original grid

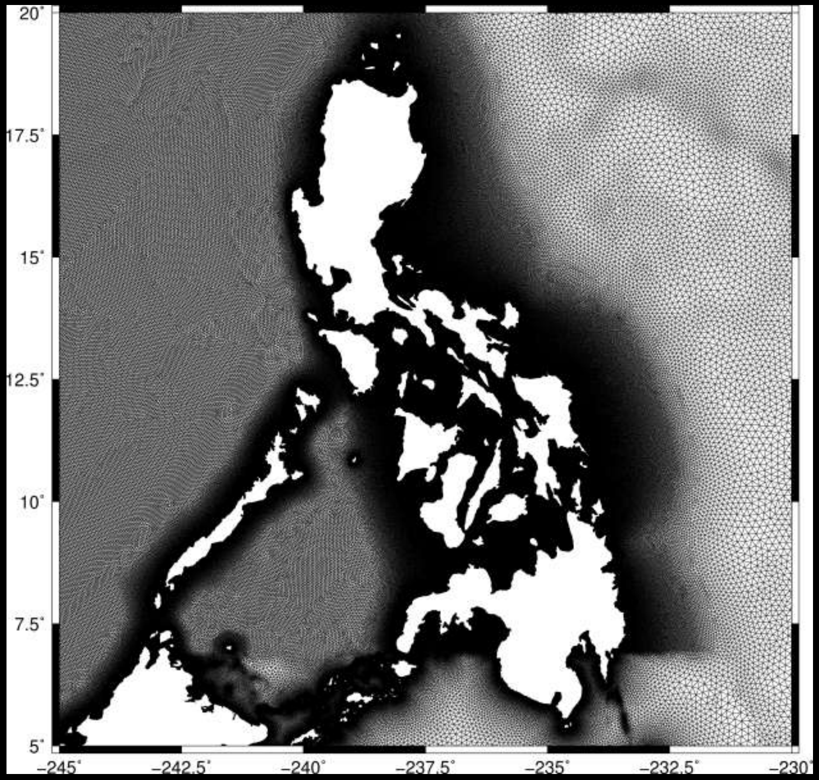




Modified grid

- ADCIRC – a numerical model used on unstructured triangular mesh grid to calculate and establish the relationship between the storm's intensity with the coastal characteristics to predict storm surge.





Unstructured mesh (FigureGen)

$$\frac{\partial \zeta}{\partial t} + \frac{1}{R\cos\phi}\left(\frac{\partial UH}{\partial \lambda} + \frac{\partial (VH\cos\phi)}{\partial \phi}\right) = 0, \tag{1}$$

$$\frac{\partial U}{\partial t} + \frac{1}{R\cos\phi} U \frac{\partial U}{\partial \lambda} + \frac{V}{R}\frac{\partial U}{\partial \phi} - \left(\frac{\tan\phi}{R} U + f\right) V = -\frac{1}{R\cos\phi}\frac{\partial}{\partial \lambda}\left[\frac{p_s}{\rho_0} + g(\zeta - \alpha\eta)\right] + \frac{\nu_T}{H}\frac{\partial}{\partial \lambda}\left[\frac{\partial UH}{\partial \lambda} + \frac{\partial UH}{\partial \phi}\right]$$
$$+ \frac{\tau_{s\lambda}}{\rho_0 H} - \tau_* U, \quad \text{and} \tag{2}$$

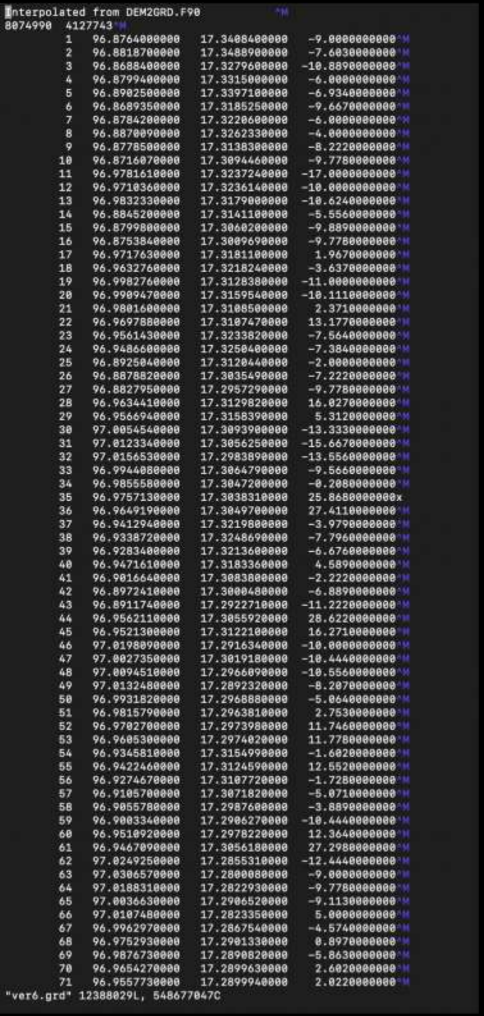
$$\frac{\partial V}{\partial t} + \frac{1}{R\cos\phi} U \frac{\partial V}{\partial \lambda} + \frac{V}{R}\frac{\partial V}{\partial \phi} + \left(\frac{\tan\phi}{R} U + f\right) U = -\frac{1}{R}\frac{\partial}{\partial \phi}\left[\frac{p_s}{\rho_0} + g(\zeta - \alpha\eta)\right] + \frac{\nu_T}{H}\frac{\partial}{\partial \phi}\left[\frac{\partial VH}{\partial \lambda} + \frac{\partial VH}{\partial \phi}\right]$$
$$+ \frac{\tau_{s\phi}}{\rho_0 H} - \tau_* V, \tag{3}$$

---

where

t = time,
λ, ϕ = degrees longitude and latitude,
ζ = the free-surface elevation relative to the geoid,
U, V = the depth-averaged horizontal velocities,
$H = \zeta + h$ = the total water column,
h = the bathymetric depth relative to the geoid,
$f = 2\Omega \sin\phi$ = the Coriolis parameter,
Ω = the angular speed of the earth,
p_s = the atmospheric pressure at the free surface,
g = acceleration due to gravity,
η = the Newtonian equilibrium tide potential,
α = the effective earth elasticity factor,
ρ_0 = the reference density of water,
$\tau_{s\lambda}$, $\tau_{s\phi}$ = the applied free-surface stress,
$\tau_* = C_f[(U^2 + V^2)^{1/2}/H]$ = the bottom friction term,
C_f = the nonlinear bottom friction coefficient, and
ν_T = the depth-averaged horizontal eddy viscosity coefficient.

ADCIRC Input Files

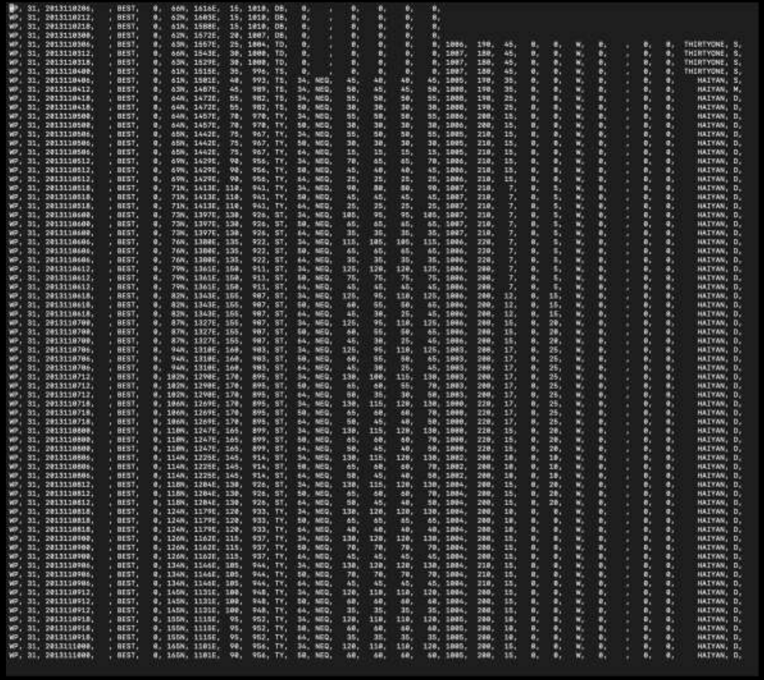


fort.14

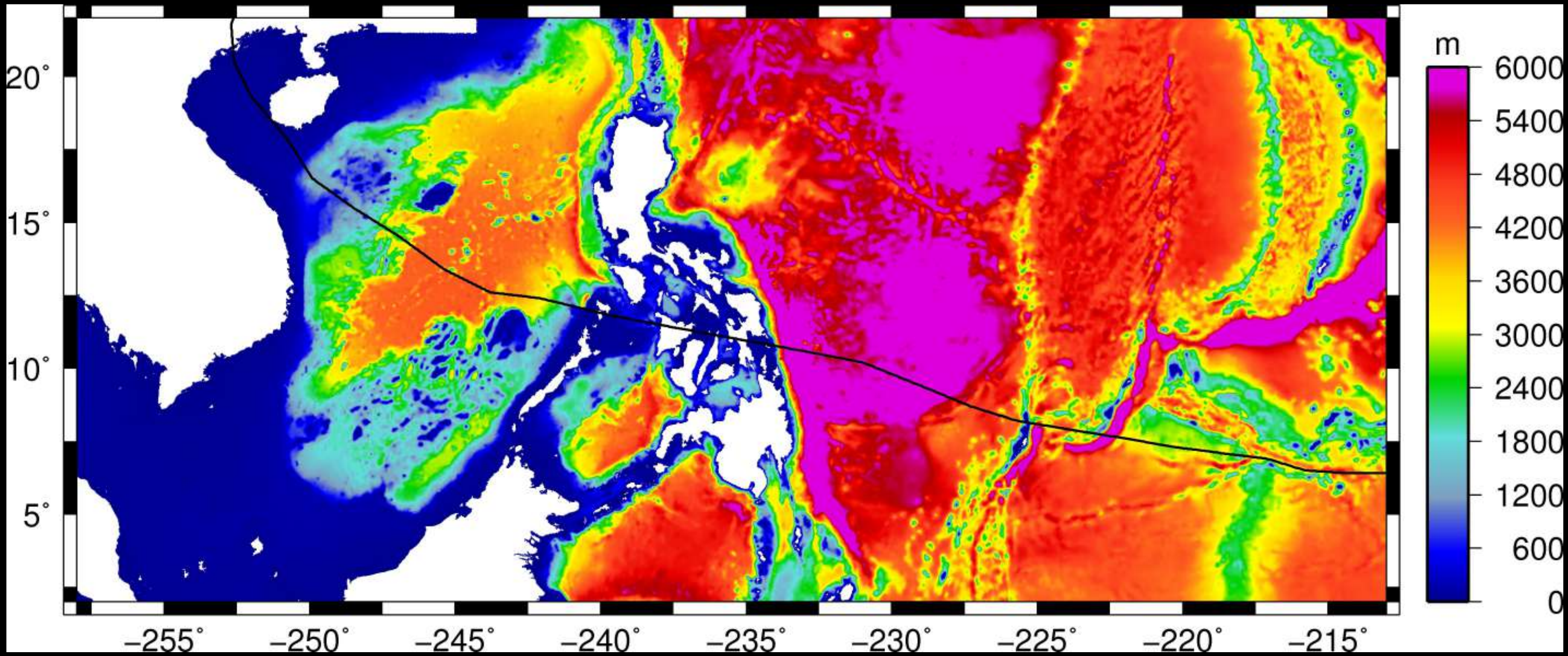
fort.13

fort.15

fort.22

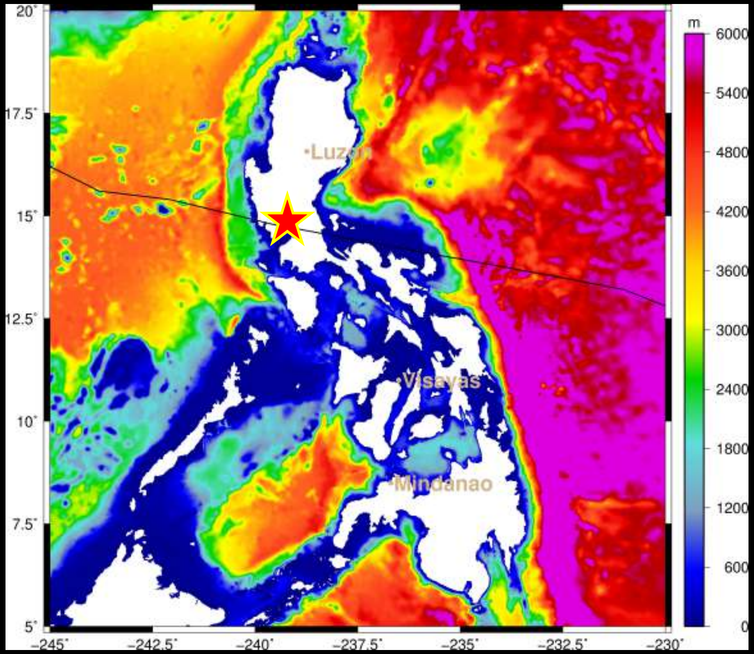


Typhoon Haiyan Validation

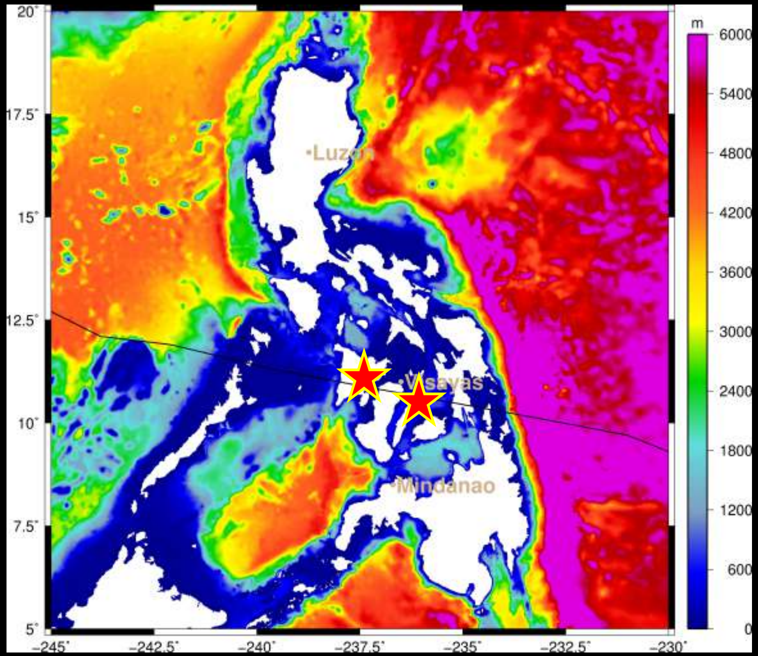


Detail of bathymetry (depth of water) around the Philippines and Typhoon Haiyan's Track (black line).

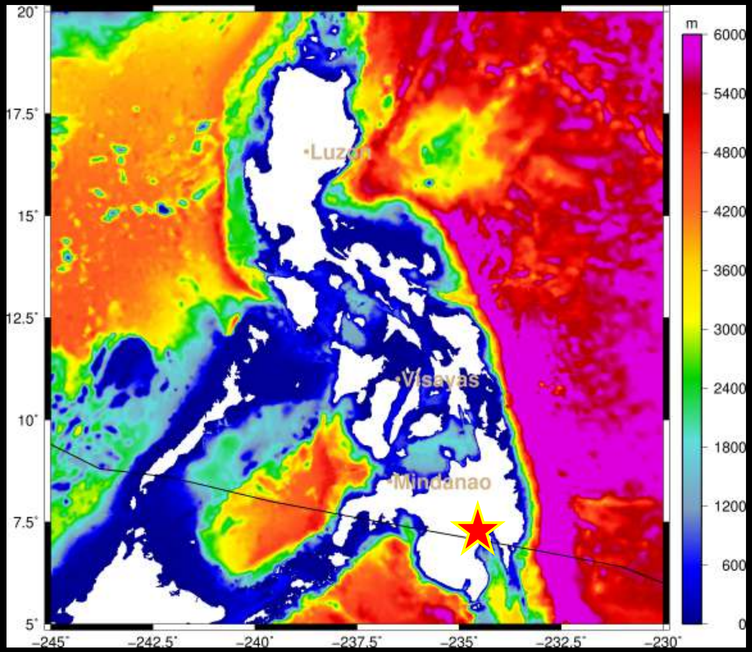
Synthetic Typhoon Haiyan Tracks



Luzon Track
+3.0N or 333 km ↑
Manila: 13 million*



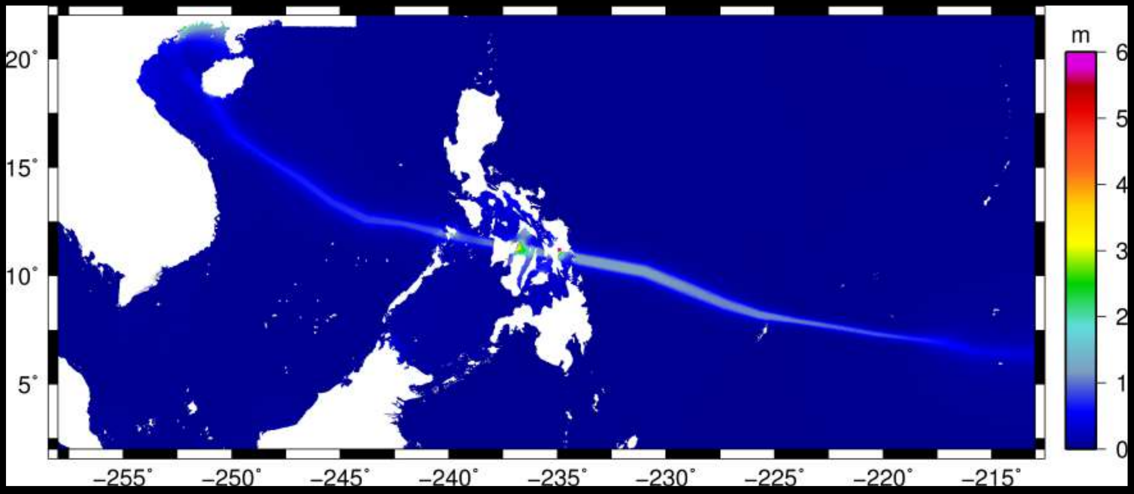
Visayas Track
-0.8S or 87 km ↓
Cebu & Iloilo: 3.5 million*



Mindanao Track
-3.5S or 420 km ↓
Davao: 2.5 million*

* Philippine Statistics Authority

Typhoon Haiyan Original Track Results

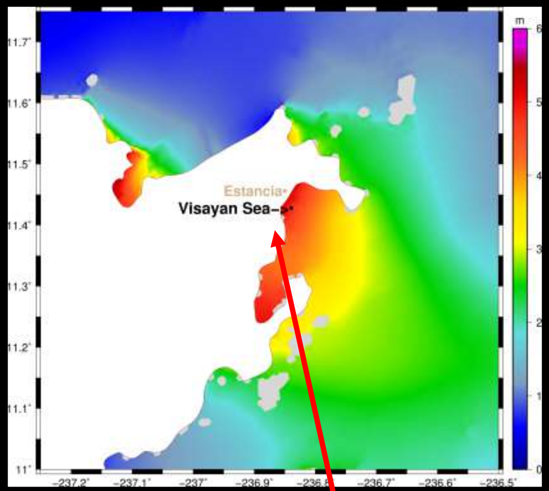


Typhoon Haiyan cyclogenesis to decay.

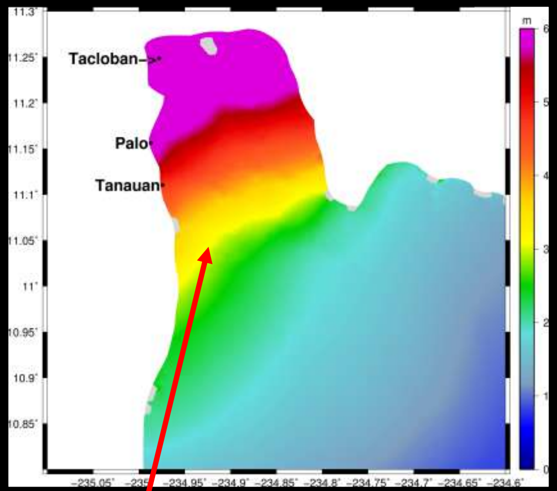
Location:	Modelled Result (m):	Field Data (m):
Tacloban	7.6	7.9[*]
Palo	6.0	5.7[*]
Tanauan	5.7	5.4[*]
Estancia	5.0	4-5[+]

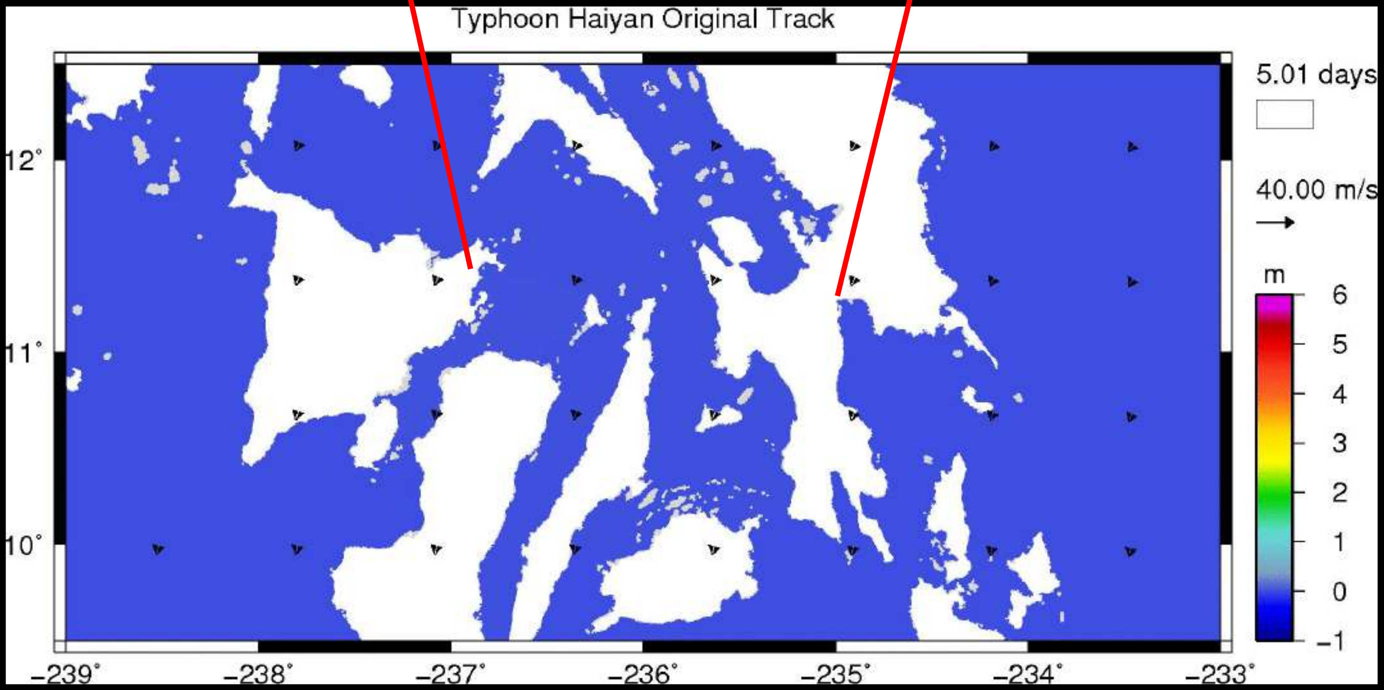
[*] (Soria et.al., 2016)
[+] (Nationwide Operational Assessment of Hazards, 2013)

Maximum elevation in the Visayan Sea.



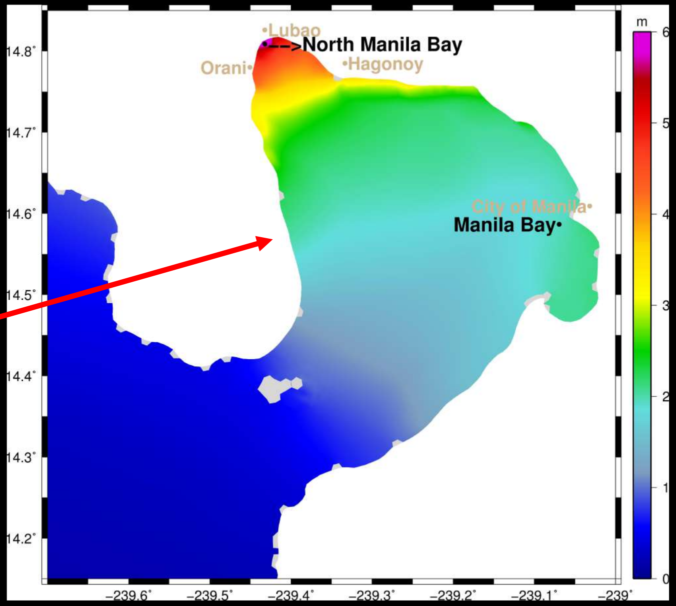
Maximum elevation in Leyte Gulf.





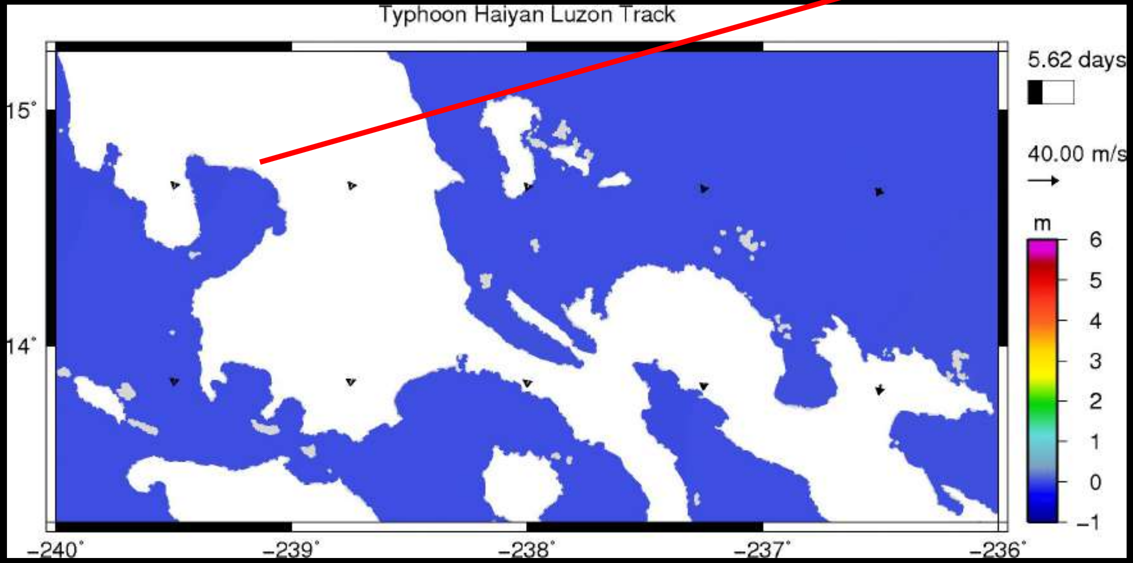
Animation of Typhoon Haiyan in the Visayas Region

Luzon Track Results

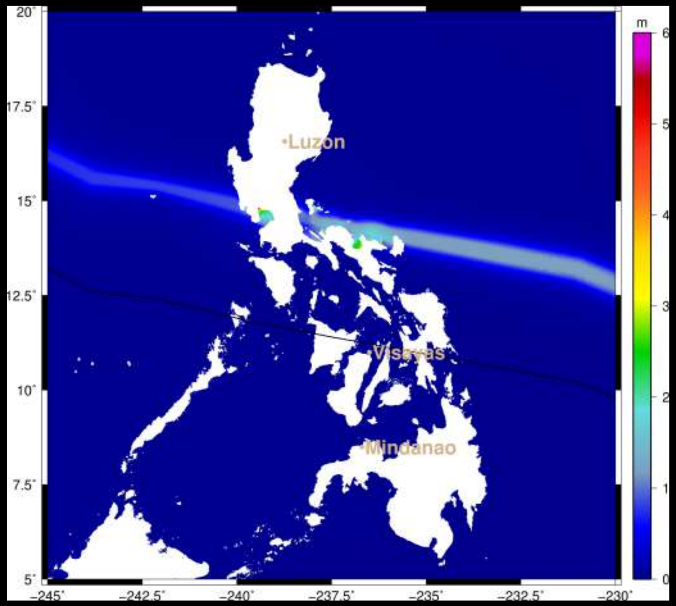


Maximum elevation in Manila Bay

Animation of Typhoon Haiyan Luzon Track.



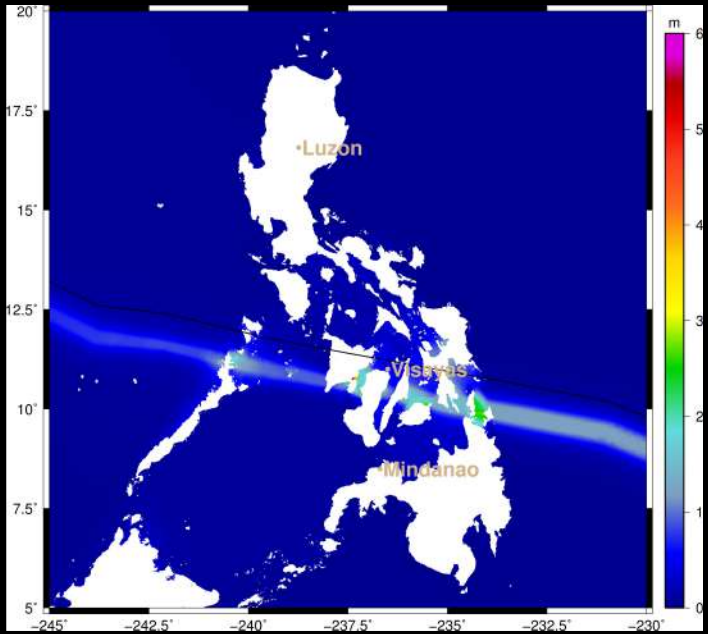
Comparison of Luzon track and original track (black line).



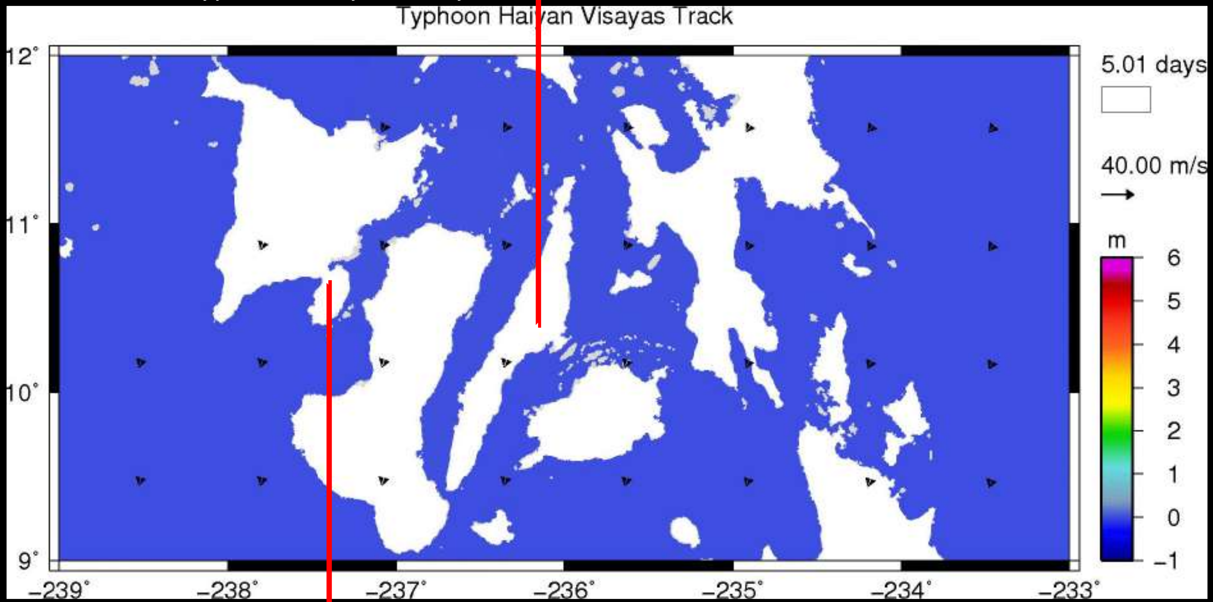
Location:	Modelled result:
Manila Bay	1.9 m
North Manila Bay	5.0 m

Visayas Track Results

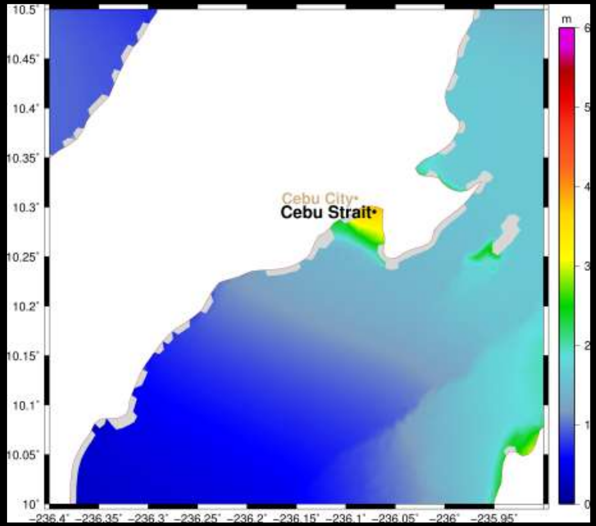
Visayas track in comparison to original track (black line)

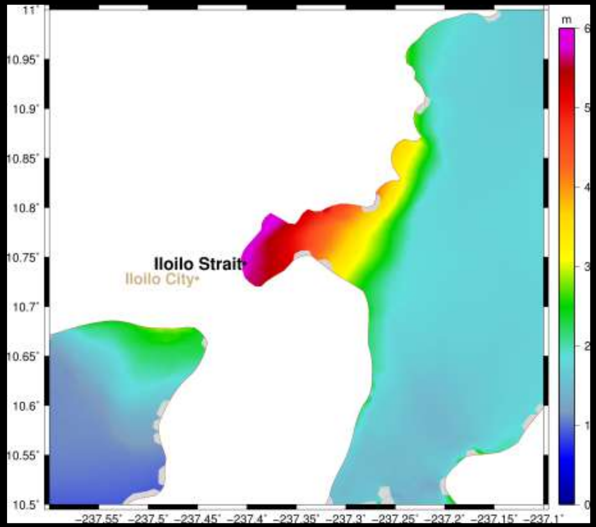


Animation of Typhoon Haiyan Visayas Track



Maximum elevation in Cebu Strait



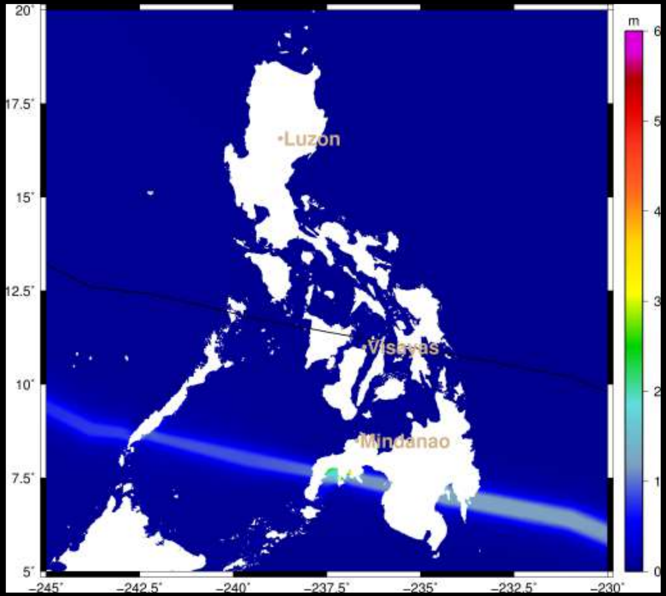


Maximum elevation in Iloilo Strait.

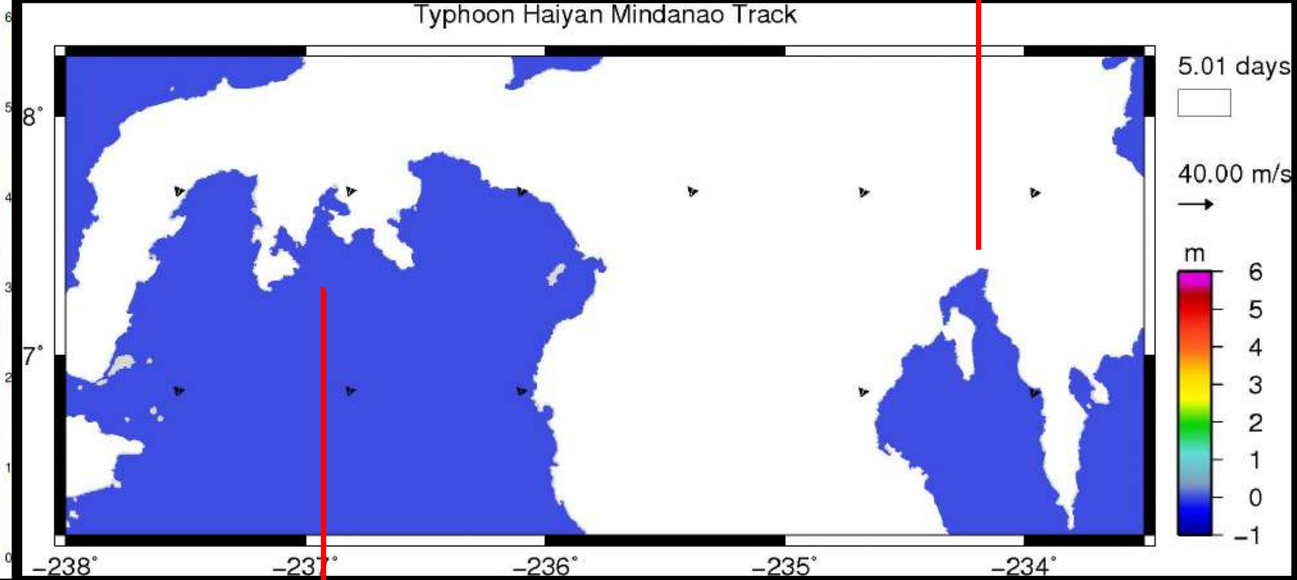
Location:	Max Elevation
Cebu Strait	3.5 m
Iloilo Strait	7.0 m

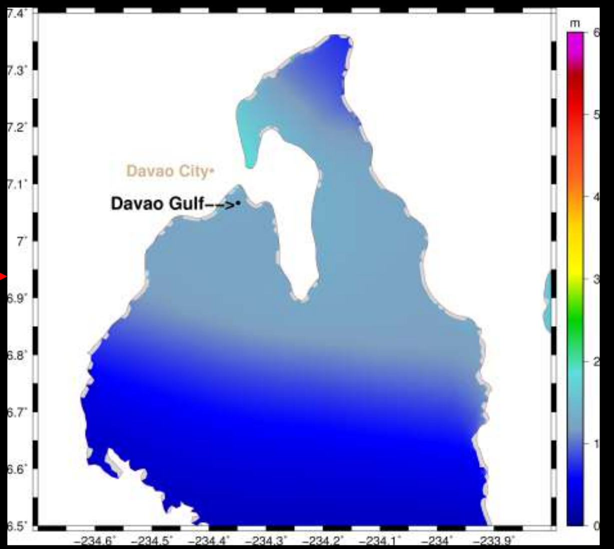
Mindanao Track Results

Mindanao track in comparison to the original track (black line).



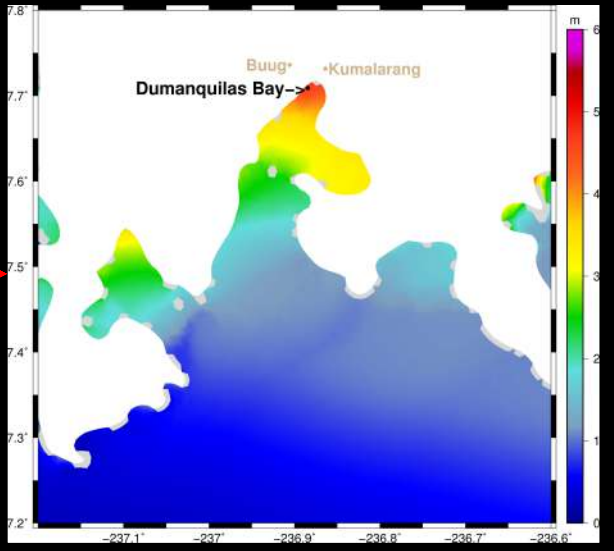
Animation of Typhoon Haiyan using Mindanao Track





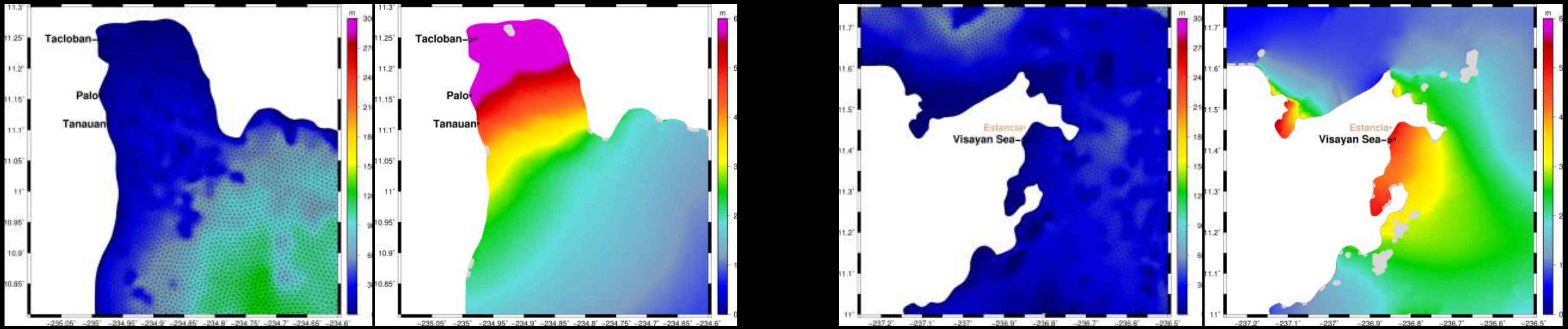
Maximum elevation in Davao Gulf.

Maximum elevation in Dumanquilas Bay

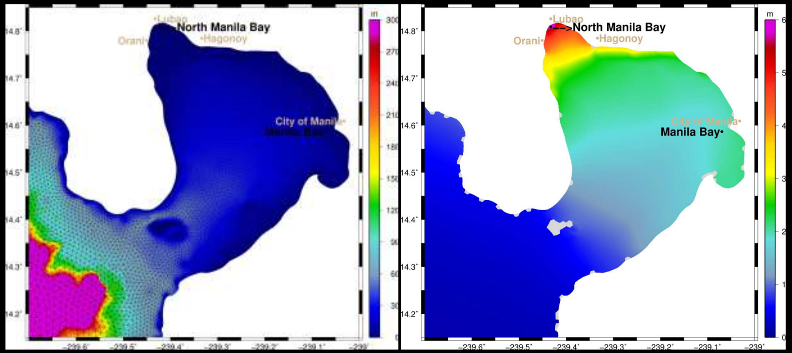


Recording Station:	Max Elevation
Davao Gulf	2.0 m
Dumanquilas Bay	4.0 m

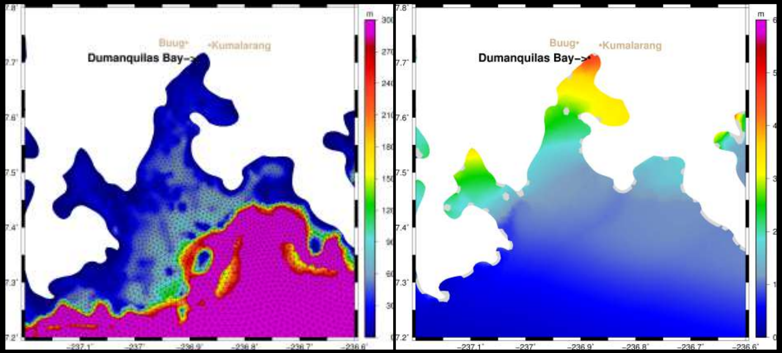
Coastal Characteristics:
(L) Gradually-sloping shelf with shallow bathymetry
(R) Steeply-sloping shelf with deep bathymetry



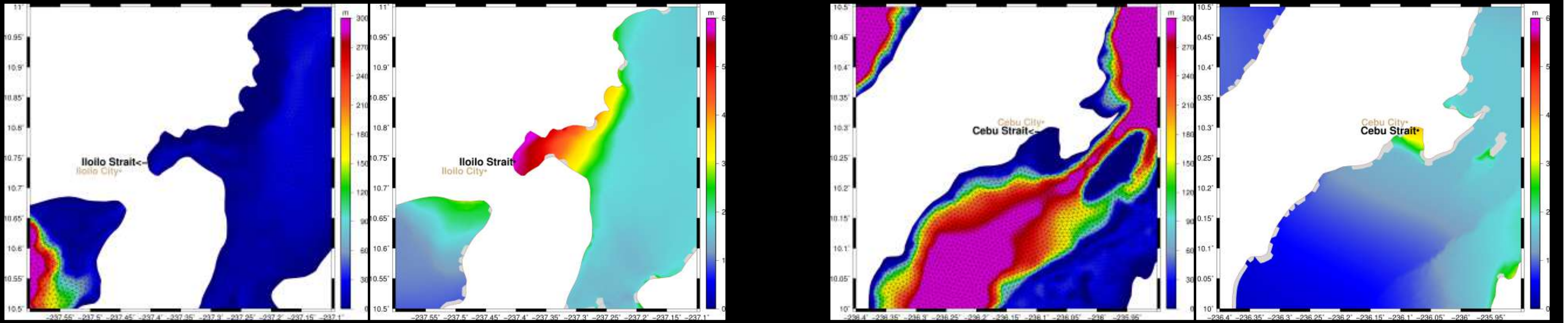
Leyte Gulf (Original Track)



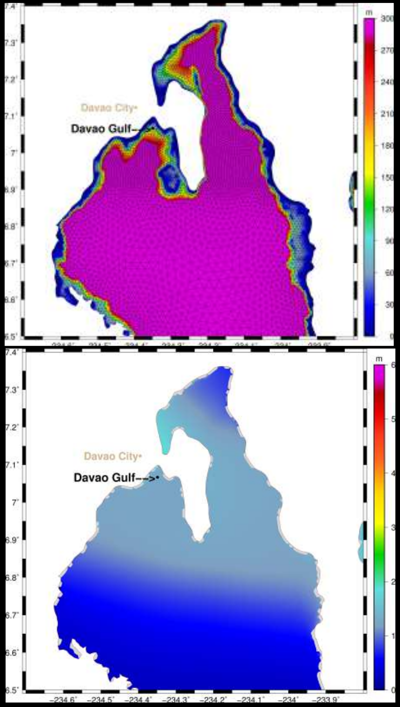
Manila Bay (Luzon Track)



Dumanquilas Bay (Mindanao Track)

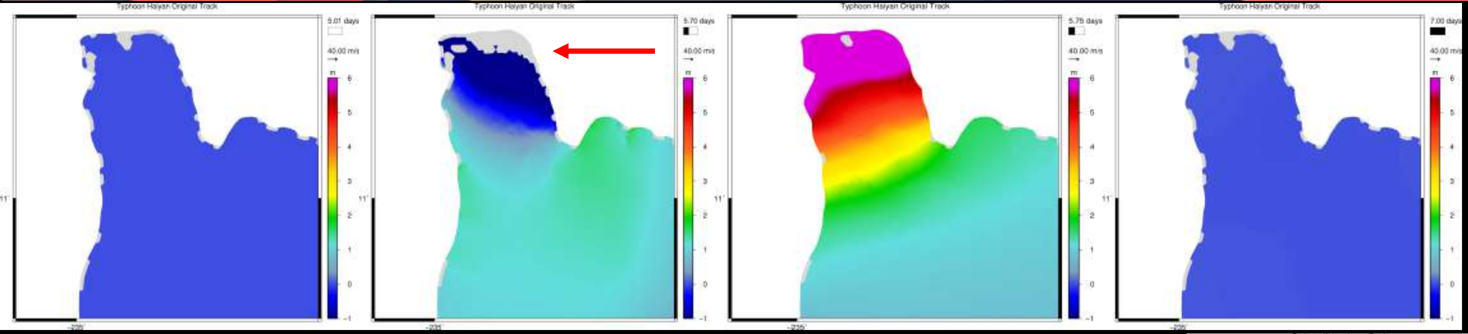


Cebu and Iloilo Strait (Visayas Track)

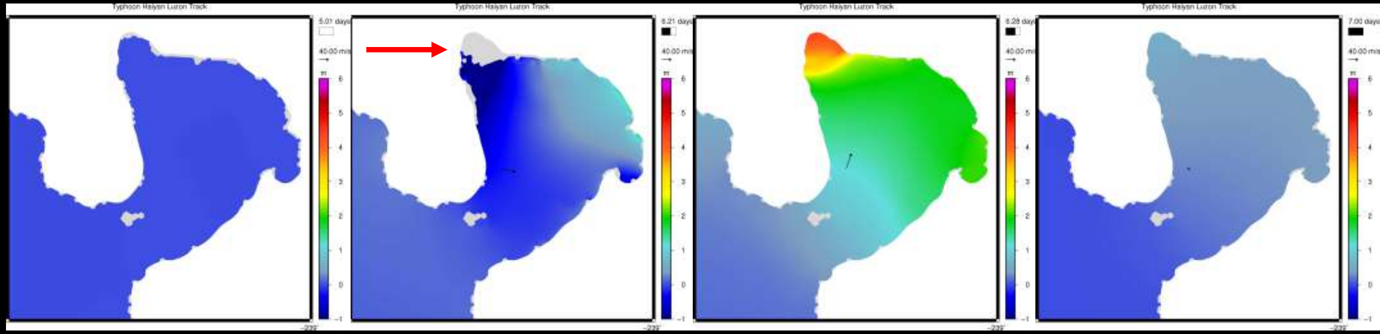


Davao Gulf (Mindanao Track)

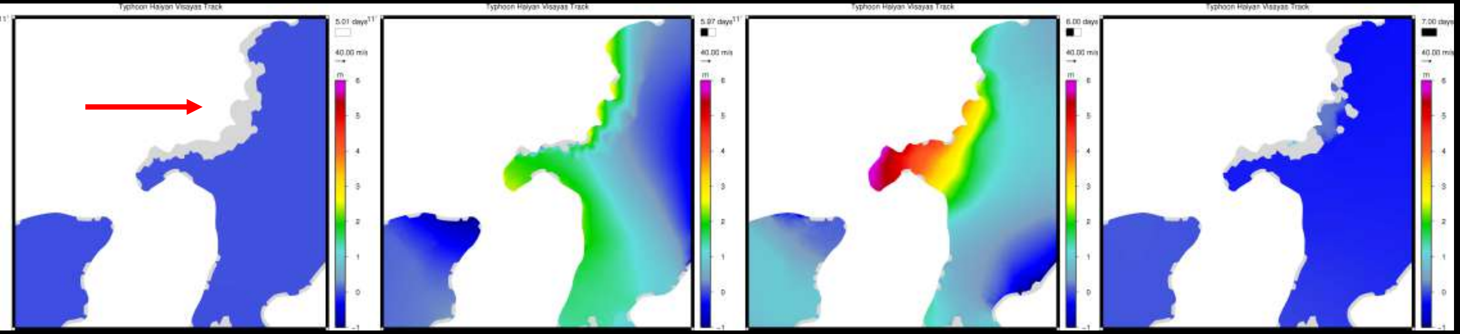
Negative Storm Surge Effect



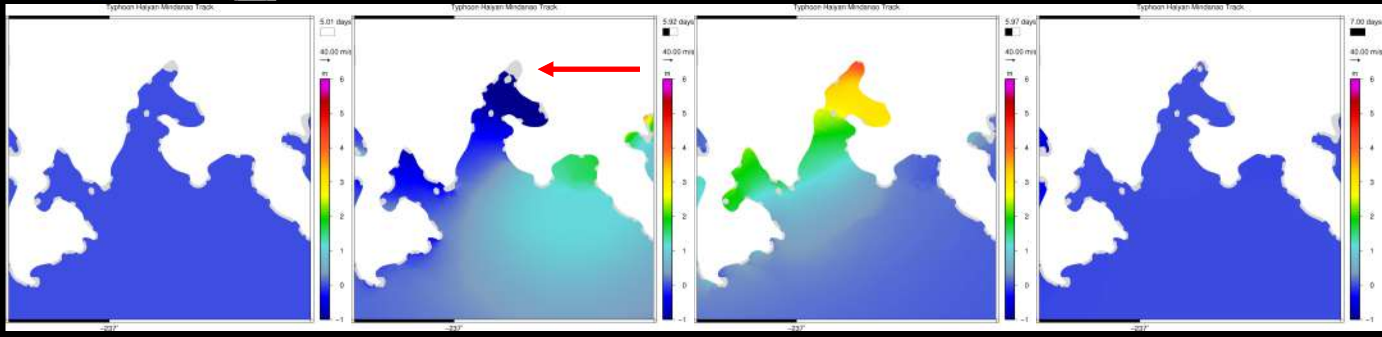
Leyte Gulf (Original Track)



Manila Bay (Luzon Track)



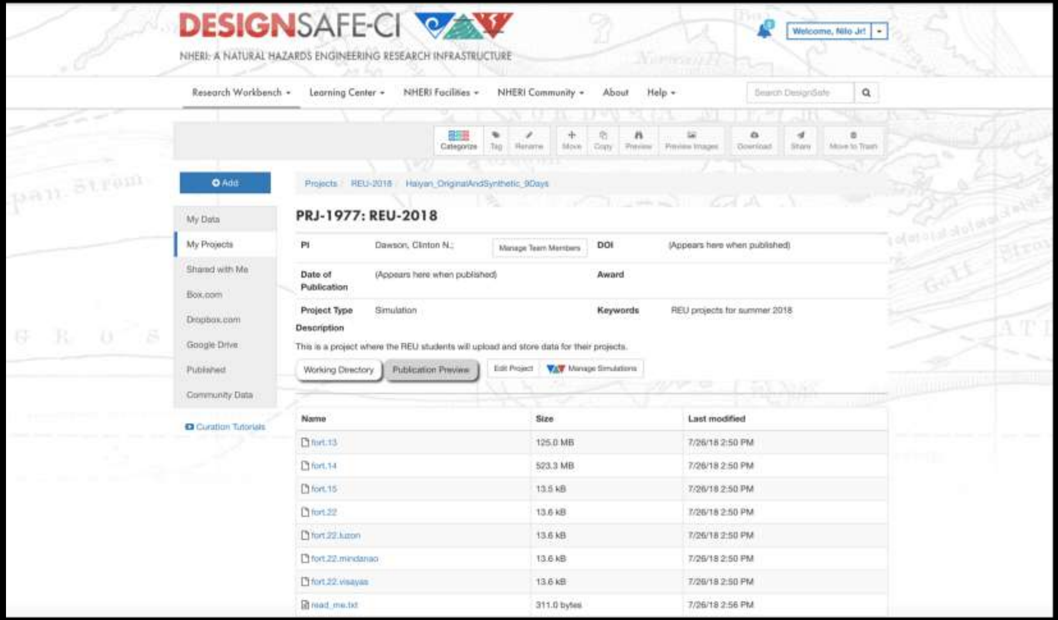
Iloilo Strait (Visayas Track)



Dumanquilas Bay (Mindanao Track)

Discussion:

- Input files are archived in DesignSafe's Data Depot
- Can be used in forecasting
- Mesh refinement to include flood plains to see inundation in coastal communities
- Identify **all** storm surge prone areas



Reflection

- Learned Fortran, Matlab, Python, Unix terminal, and ADCIRC.
- Processes of how an engineering research works.
- Make in impact in my community.


NEES@UTexas

Reflection

- Future Opportunities: Computing4Change & SPICE (Supporting Pacific Indigenous Computing in Excellence)

Acknowledgement

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- Graduate students: Chen Chen and Mark Loveland
- Dr. Joannes J. Westerink of University of Notre Dame
- Dr. Karina Vielma and Ms. Rosalia Gomez
- Co-NHERI REU students

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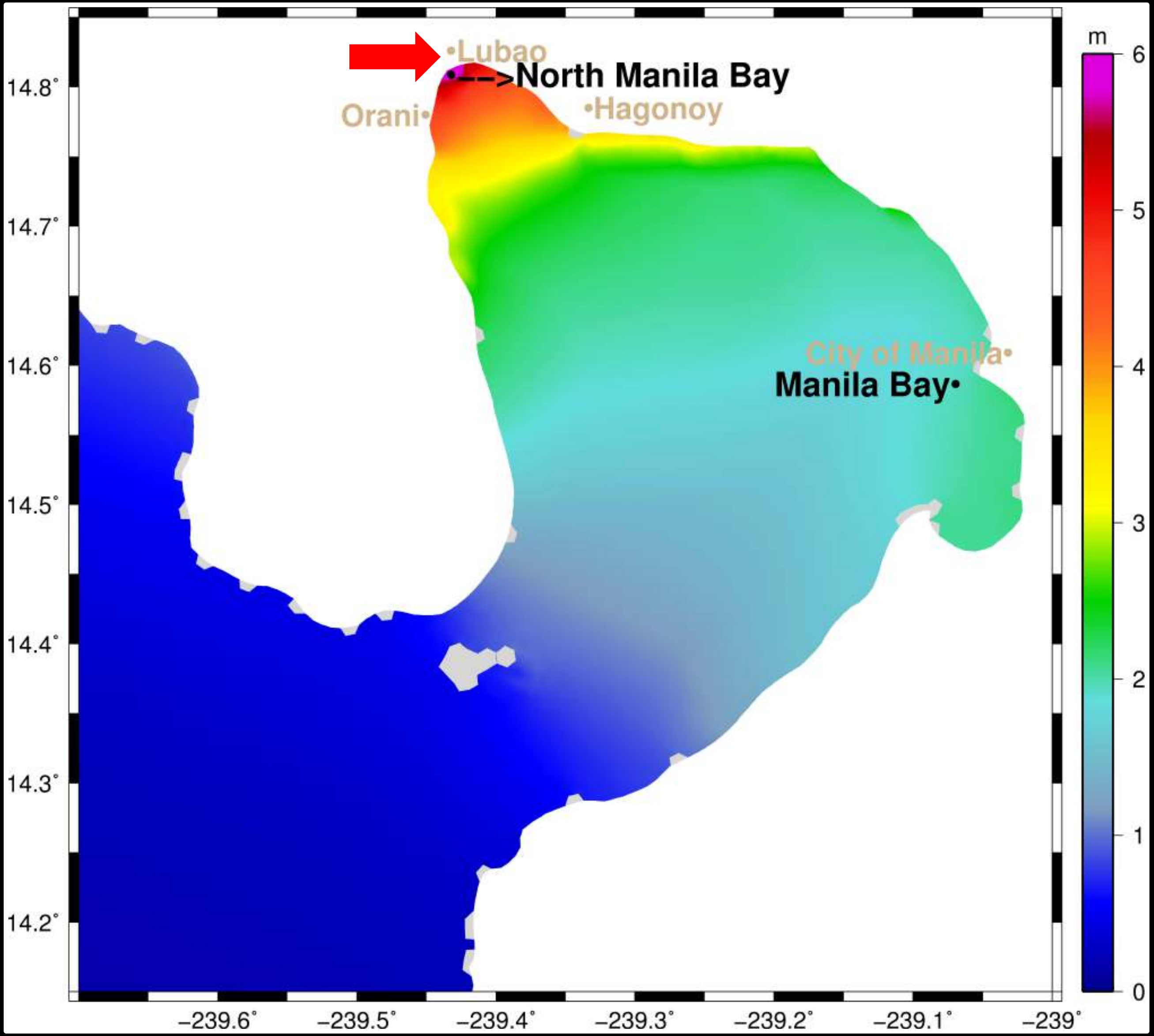
•Lubao
-->North Manila Bay
Orani•
•Hagonoy
City of Manila•
Manila Bay•
14.8°
14.7°
14.6°
14.5°
14.4°
14.3°
14.2°
−239.6°
−239.5°
−239.4°
−239.3°
−239.2°
−239.1°
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